

Pulsed Lidar Measurements of Atmospheric CO₂ Column Absorption and Range during the ASCENDS 2009-2011 Airborne Campaigns

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Abstract:

We have developed a pulsed lidar technique for measuring the tropospheric CO₂ concentrations as a candidate for NASA's ASCENDS mission and have demonstrated the CO₂ and O₂ measurements from aircraft. Our technique uses two pulsed lasers allowing simultaneous measurement of a single CO₂ absorption line near 1572 nm, O₂ extinction in the Oxygen A-band, surface height and backscatter profile. The lasers are stepped in wavelength across the CO₂ line and an O₂ line doublet during the measurement. The column densities for the CO₂ and O₂ are estimated from the differential optical depths (DOD) of the scanned absorption lines via the IPDA technique.

For the 2009 ASCENDS campaign we flew the CO₂ lidar only on a Lear-25 aircraft, and measured the absorption line shapes of the CO₂ line using 20 wavelength samples per scan. Measurements were made at stepped altitudes from 3 to 12.6 km over the Lamont OK, central Illinois, North Carolina, and over the Virginia Eastern Shore. Although the received signal energies were weaker than expected for ASCENDS, clear CO₂ line shapes were observed at all altitudes. Most flights had 5-6 altitude steps with 200-300 seconds of recorded measurements per step. We averaged every 10 seconds of measurements and used a cross-correlation approach to estimate the range to the scattering surface and the echo pulse energy at each wavelength. We then solved for the best-fit CO₂ absorption line shape, and calculated the DOD of the fitted CO₂ line, and computed its statistics at the various altitude steps. We compared them to CO₂ optical depths calculated from spectroscopy based on HITRAN 2008 and the column number densities calculated from the airborne in-situ readings.

The 2009 measurements have been analyzed in detail and they were similar on all flights. The results show clear CO₂ line shape and absorption signals, which follow the expected changes with aircraft altitude from 3 to 13 km. They showed the expected nearly the linear dependence of DOD vs altitude. The measurements showed ~1 ppm random errors for 8-10 km altitudes and ~30 sec averaging times.

For the 2010 ASCENDS campaigns we flew the CO₂ lidar on the NASA DC-8 and added an O₂ lidar channel. During July 2010 we made measurements of CO₂ and O₂ column absorption during longer flights over Railroad Valley NV, the Pacific Ocean and over Lamont OK. CO₂ measurements were made with 30 steps/scan, 300 scans/sec and improved line resolution and receiver sensitivity. Analysis of the 2010 CO₂ measurements shows the expected ~linear change of DOD with altitude. For measurements at altitudes > 6 km the random errors were 0.3 ppm for 80 sec averaging times. For the summer 2011 ASCENDS campaigns we made further improvements to the lidar's CO₂ line scan and receiver sensitivity. The seven flights in the 2011 Ascends campaign were flown over a wide variety of surface and cloud conditions in the US, which produced a wide variety of lidar signal conditions. Details of the lidar measurements and their analysis will be described in the presentation.